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Introducing T-SQL and Data Management Systems

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This first chapter introduces you to some of the fundamentals of the design and architecture of relational databases and presents a brief description of SQL as a language. If you are new to SQL and database technologies, this chapter will provide a foundation to help ensure the rest of the book is as useful as possible. If you are already comfortable with the concepts of relational databases and Microsoft's implementation, you might want to skip ahead to Chapter 2, "SQL Server Fundamentals," or Chapter 3, "SQL Server Tools." Both of these chapters introduce the features and tools in SQL Server 2005 and 2008 and discuss how they are used to write T-SQL.

T-SQL Language

I have mentioned to my colleagues and anyone else who might have been listening that one day I was going to write a version of Parker Brother's Trivial Pursuit entitled "Trivial Pursuit: Geek Edition." This section gives you some background on the T-SQL language and provides the information you need to get the orange history wedge on the topic of "Database History" in Trivial Pursuit: Geek Edition.

T-SQL is Microsoft's implementation of a standard established by the American National Standards Institute (ANSI) for the Structured Query Language (SQL). SQL was first developed by researchers at IBM. They called their first pre-release version of SQL "SEQUEL," which is a pseudo-acronym for **S**tructured **E**nglish **QUE**ry **L**anguage. The first release version was renamed to SQL, dropping the English part but retaining the pronunciation to identify it with its predecessor. As of the release of SQL Server 2008, several implementations of SQL by different stakeholders are in the database marketplace. As you sojourn through the sometimes mystifying lands of database technology you will undoubtedly encounter these different varieties of SQL. What makes them all similar is the ANSI standard to which IBM, more than any other vendor, adheres to with tenacious rigidity. However, what makes the many implementations of SQL different are the customized programming objects and extensions to the language that make it unique to that particular platform.

Microsoft SQL Server 2008 implements the 2003 ANSI standard. The term "implements" is of significance. T-SQL is not fully compliant with ANSI standards in any of its implementations; neither is Oracle's P/L SQL, Sybase's SQLAnywhere, or the open-source MySQL. Each implementation has custom extensions and variations that deviate from the established standard. ANSI has three levels of compliance: Entry, Intermediate, and Full. T-SQL is certified at the entry level of ANSI compliance. If you strictly adhere to the features that are ANSI-compliant, the same code you write for Microsoft SQL Server should work on any ANSI-compliant platform; that's the theory, anyway. If you find that you are writing cross-platform queries, you will most certainly need to take extra care to ensure that the syntax is perfectly suited for all the platforms it affects. The simple reality of this issue is that very few people will need to write queries to work on multiple database platforms. The standards serve as a guideline to help keep query languages focused on working with data, rather than other forms of programming. This may slow the evolution of relational databases just enough to keep us sane.

Programming Language or Query Language?

T-SQL was not really developed to be a full-fledged programming language. Over the years, the ANSI standard has been expanded to incorporate more and more procedural language elements, but it still lacks the power and flexibility of a true programming language. Antoine, a talented programmer and friend of mine, refers to SQL as "Visual Basic on Quaaludes." I share this bit of information not because I agree with it, but because I think it is funny. I also think it is indicative of many application developers' view of this versatile language.

T-SQL was designed with the exclusive purpose of data retrieval and data manipulation. Although T-SQL, like its ANSI sibling, can be used for many programming-like operations, its effectiveness at these tasks varies from excellent to abysmal. That being said, I am still more than happy to call T-SQL a programming language if only to avoid someone calling me a SQL "queryers." However, the undeniable fact still remains: as a programming language, T-SQL falls short. The good news is that as a data retrieval and set manipulation language it is exceptional. When T-SQL programmers try to use T-SQL like a programming language, they invariably run afoul of the best practices that ensure the efficient processing and execution of the code. Because T-SQL is at its best when manipulating sets of data, try to keep that fact foremost in your thoughts during the process of developing T-SQL code.

With the release of SQL Server 2005, Microsoft muddied the waters a bit with the ability to write calls to the database in a programming language like C# or VB.NET, rather than in pure SQL. SQL Server 2008 also supports this very flexible capability, but use caution! Although this is a very exciting innovation in data access, the truth of the matter is that almost all calls to the database engine must still be manipulated so that they appear to be T-SQL based.

Performing multiple recursive row operations or complex mathematical computations is quite possible with T-SQL, but so is writing a .NET application with Notepad. When I was growing up my father used to make a point of telling me that "Just because you can do something doesn't mean you should." The point here is that oftentimes SQL programmers will resort to creating custom objects in their code that are inefficient as far as memory and CPU consumption are concerned. They do this because it is the easiest and quickest way to finish the code. I agree that there are times when a quick solution is the best, but future performance must always be taken into account.

One of the systems I am currently working on is a perfect example of this problem. The database started out very small, with a small development team and a small number of customers using the database. It worked great. However, the database didn't stay small, and as more and more customers started using

the system, the number of transactions and code executions increased exponentially. It wasn't long before inefficient code began to consume all the available CPU resources. This is the trap of writing expedient code instead of efficient code. Another of my father's favorite sayings is "Why is there never enough time to do the job right, but plenty of time to do it twice?" This book tries to show you the best way to write T-SQL so that you can avoid writing code that will bring your server to its knees, begging for mercy. Don't give in to the temptation to write sloppy code just because it is a "one time deal." I have seen far too many times when that one-off ad-hoc query became a central piece of an application's business logic.

What's New in SQL Server 2008

When SQL Server 2005 was released, it had been five years since the previous release and the changes to the product since the release of SQL Server 2000 were myriad and significant. Several books and hundreds of websites were published that were devoted to the topic of "What's New in SQL Server 2005." With the release of SQL Server 2008, however, there is much less buzz and not such a dramatic change to the platform. However, the changes in the 2008 release are still very exciting and introduce many changes that T-SQL and application developers have been clamoring for. Since these changes are sprinkled throughout the capabilities of SQL Server, I won't spend a great deal of time describing all the changes here. Instead, throughout the book I will identify those changes that are applicable to the subject being described. In this introductory chapter I want to quickly mention two of the significant changes to SQL that will invariably have an impact on the SQL programmer: the incorporation of the .NET Framework with SQL Server and the introduction of Microsoft Language Integrated Query (LINQ).

Kiss T-SQL Goodbye?

I have been hearing for years that T-SQL and its ANSI counterpart, SQL, were antiquated languages and would soon be phased out. However, every database vendor, both small and large, has devoted millions of dollars to improving their version of this versatile language. Why would they do that if it were a dead language? The simple fact of the matter is that databases are built and optimized for the set-based operations that the SQL language offers. Is there a better way to access and manipulate data? Probably so, but with every major industry storing their data in relational databases, the reign of SQL is far from over.

I worked for a great guy at a Microsoft partner company who was contracted by Microsoft to develop and deliver a number of SQL Server and Visual Studio evangelism presentations. Having a background in radio sales and marketing, he came up with a cool tagline about SQL Server and the .NET Framework that said "SQL Server and .NET — Kiss T-SQL Goodbye." He was quickly dissuaded by his team when presented with the facts. However, Todd wasn't completely wrong. What his catchy tagline could have said and been accurate was "SQL Server and .NET — Kiss Inefficient, CPU-Hogging T-SQL Code Goodbye."

Two significant improvements in data access over the last two releases of SQL Server have offered fuel for the "SQL is dead" fire. As I mentioned briefly before, these are the incorporation of the .NET Framework and the development of LINQ. LINQ is Microsoft's latest application data-access technology. It enables Visual Basic and C# applications to use set-oriented queries that are developed in C# or VB, rather than requiring that the queries be written in T-SQL. Building in the .NET Framework to the SQL Server engine enables developers to create SQL Server programming objects such as stored procedures, functions, and aggregates using any .NET language and compiling them into Common Language Runtime (CLR) assemblies that can be referenced directly by the database engine.

So with the introduction of LINQ in SQL Server 2008 and CLR integration in SQL Server 2005, is T-SQL on its death bed? No, not really. Reports of T-SQL's demise are premature and highly exaggerated. The ability to create database programming objects in managed code instead of SQL does not mean that T-SQL is in danger of becoming extinct. Likewise, the ability to create set-oriented queries in C# and VB does not sound the death knell for T-SQL. SQL Server's native language is still T-SQL. LINQ will help in the rapid development of database applications, but it remains to be seen if this technology will match the performance of native T-SQL code run from the server. This is because LINQ data access still must be translated from the application layer to the database layer, but T-SQL does not. It's a fantastic and flexible access layer for smaller database applications, but for large, enterprise-class applications, LINQ, like embedded SQL code in applications before it, falls short of pure T-SQL in terms of performance.

What was true then is true now. T-SQL will continue to be the core language for applications that need to add, extract, and manipulate data stored on SQL Server. Until the data engine is completely re-engineered (and that day will inevitably come), T-SQL will be at the heart of SQL Server.

Database Management Systems

A database management system (DBMS) is a set of programs designed to store and maintain data. The role of the DBMS is to manage the data so that the consistency and integrity of the data is maintained above all else. Quite a few types and implementations of database management systems exist:

- **Hierarchical database management systems (HDBMS)** — Hierarchical databases have been around for a long time and are perhaps the oldest of all databases. They were (and in some cases still are) used to manage hierarchical data. They have several limitations, such as being able to manage only single trees of hierarchical data and the inability to efficiently prevent erroneous or duplicate data. HDBMS implementations are getting increasingly rare and are constrained to specialized, and typically non-commercial, applications.
- **Network database management system (NDBMS)** — The NDBMS has been largely abandoned. In the past, large organizational database systems were implemented as network or hierarchical systems. The network systems did not suffer from the data inconsistencies of the hierarchical model, but they did suffer from a very complex and rigid structure that made changes to the database or its hosted applications very difficult.
- **Relational database management system (RDBMS)** — An RDBMS is a software application used to store data in multiple related tables using SQL as the tool for creating, managing, and modifying both the data and the data structures. An RDBMS maintains data by storing it in tables that represent single entities, such as "Customer" and "Sale" and storing information about the relationship of these tables to each other in yet more tables managed by the system which define the relationship between the Sale table and the Customer table. The concept of a relational database was first described by E. F. Codd, an IBM scientist who defined the relational model in 1970. Relational databases are optimized for recording transactions and the resultant transactional data. Most commercial software applications use an RDBMS as their data store. Because SQL was designed specifically for use with an RDBMS, I will spend a little extra time covering the basic structures of an RDBMS later in this chapter.
- **Object-oriented database management system (ODBMS)** — The ODBMS emerged a few years ago as a system where data was stored as objects in a database. ODBMS supports multiple classes of objects and inheritance of classes along with other aspects of object orientation. Currently, no international standard exists that specifies exactly what an ODBMS is and what it isn't.

Because ODBMS applications store objects instead of related entities, they make the system very efficient when dealing with complex data objects and object-oriented programming (OOP) languages such as the .NET languages from Microsoft as well as C and Java. When ODBMS solutions were first released, they were quickly touted as the ultimate database system and predicted to make all other database systems obsolete. However, they never achieved the wide acceptance that was predicted. They do have a very valid position in the database market, but it is a niche market held mostly within the Computer-Aided Design (CAD) and telecommunications industries.

- **Object-relational database management system (ORDBMS)** — The ORDBMS emerged from existing RDBMS solutions when the vendors who produced the relational systems realized that the ability to store objects was becoming more important. They incorporated mechanisms to be able to store classes and objects in the relational model. ORDBMS implementations have, for the most part, usurped the market that the ODBMS vendors were targeting for a variety of reasons that I won't expound on here. However, Microsoft's SQL Server, with its `xml` data type, the incorporation of the .NET Framework, and the new `filestream` data type introduced with SQL Server 2008, could arguably be labeled an ORDBMS. The `filestream` data type is discussed in more detail later in this chapter and in Appendix E.

SQL Server as a Relational Database Management System

This section introduces you to the concepts behind relational databases and how they are implemented from a Microsoft viewpoint. This will, by necessity, skirt the edges of database object creation, which is covered in great detail in Chapter 13, so for the purpose of this discussion I will avoid the exact mechanics and focus on the final results.

As I mentioned earlier, a relational database stores all its data inside tables. Ideally, each table will represent a single entity or object. You would not want to create one table that contained data about both dogs and cars. That isn't to say you couldn't do this, but it wouldn't be very efficient or easy to maintain if you did.

Tables

Tables are divided up into rows and columns. Each row must be able to stand on its own, without a dependency to other rows in the table. The row must represent a single, complete instance of the entity the table was created to represent. Each column in the row contains specific attributes that help define the instance. This may sound a bit complex, but it is actually very simple. To help illustrate, consider a real-world entity, such as an employee. If you want to store data about an employee, you would need to create a table that has the properties you need to record data about your employee. For simplicity's sake, call your table Employee.

When you create your employee table, you also need to decide which attributes of the employee you want to store. For the purposes of this example, suppose that you have decided to store the employee's last name, first name, Social Security number, department, extension, and hire date. The resulting table would look something like that shown in Figure 1-1.

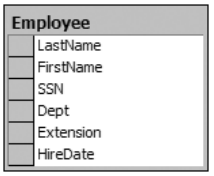

Figure 1-1

The data in the table would look something like that shown in Figure 1-2.

LastName	FirstName	SSN	Dept	Extension	HireDate
Flintstone	Fred	123456789	Operations	9876	11/12/2000
Slate	George	987654321	Management	3456	4/14/1999

Figure 1-2

Primary Keys

To manage the data in your table efficiently, you need to be able to uniquely identify each individual row in the table. It is much more difficult to retrieve, update, or delete a single row if there is not a single attribute that identifies each row individually. In many cases, this identifier is not a descriptive attribute of the entity. For example, the logical choice to uniquely identify your employee is the Social Security number attribute. However, there are a couple of reasons why you would not want to use the Social Security number as the primary mechanism for identifying each instance of an employee, both boiling down to two different areas: security and efficiency.

When it comes to security, what you want to avoid is the necessity of securing the employee's Social Security number in multiple tables. Because you will most likely be using the key column in multiple tables to form your relationships (more on that in a moment), it makes sense to substitute a non-descriptive key. In this way you avoid the issue of duplicating private or sensitive data in multiple locations to provide the mechanism to form relationships between tables.

As far as efficiency is concerned, you can often substitute a non-data key that has a more efficient or smaller data type associated with it. For example, in your design you might have created the Social Security number with either a character data type or an integer. If you have fewer than 32,767 employees, you can use a double-byte integer instead of a 4-byte integer or 10-byte character type; besides, integers process faster than characters.

So, instead of using the Social Security number, you will assign a non-descriptive key to each row. The key value used to uniquely identify individual rows in a table is called a ***primary key***. (You will still want to ensure that every Social Security number in your table is unique and not null, but you will use a different method to guarantee this behavior without making it a primary key.)

A non-descriptive key doesn't represent anything else with the exception of being a value that uniquely identifies each row or individual instance of the entity in a table. This will simplify the joining of this table to other tables and provide the basis for a "relation." In this example you will simply alter the table by adding an EmployeeKey column that will uniquely identify every row in the table, as shown in Figure 1-3.

Figure 1-3

With the EmployeeKey column, you have an efficient, easy-to-manage primary key.

Each table can have only one primary key, which means that this key column is the primary method for uniquely identifying individual rows. It doesn't have to be the only mechanism for uniquely identifying individual rows; it is just the "primary" mechanism for doing so. Primary keys can never be null, and they must be unique. Primary keys can also be combinations of columns (though I'll explain later why I am a firm believer that primary keys should typically be single-column keys). If you have a table where two columns in combination are unique, while either single column is not, you can combine the two columns as a single primary key, as illustrated in Figure 1-4.

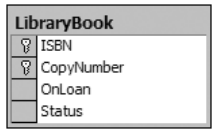

Figure 1-4

In this example, the LibraryBook table is used to maintain a record of every book in the library. Because multiple copies of each book can exist, the ISBN column is not useful for uniquely identifying each book. To enable the identification of each individual book, the table designer decided to combine the ISBN column with the copy number of each book. Personally, I avoid the practice of using multiple column keys. I prefer to create a separate column that can uniquely identify the row. This makes it much easier to write join queries (covered in detail in Chapter 8). The resulting code is cleaner and the queries are generally more efficient. For the library book example, a more efficient mechanism might be to assign each book its own number. The resulting table would look like that shown in Figure 1-5.

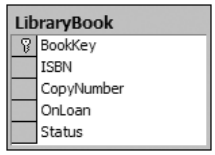

Figure 1-5

Table Columns

As previously described, a table is a set of rows and columns used to represent an entity. Each row represents an instance of the entity. Each column in the row will contain at most one value that represents an attribute, or property, of the entity. For example, consider the employee table; each row represents a single instance of the employee entity. Each employee can have one and only one first name, last name, SSN, extension, or hire date, according to your design specifications. In addition to deciding which attributes you want to maintain, you must also decide how to store those attributes. When you define columns for your tables, you must, at a minimum, define three things:

- The name of the column
- The data type of the column
- Whether the column can support null

Column Names

Keep the names simple and intuitive (such as LastName or EmployeeID) instead of more cumbersome names (such as EmployeeLastName and EmployeeIdentificationNumber). For more information, see Chapter 8.

Data Types

The general rule on data types is to use the smallest one you can. This conserves memory usage and disk space. Also keep in mind that SQL Server processes numbers much more efficiently than characters, so use numbers whenever practical. I have heard the argument that numbers should be used only if you plan on performing mathematical operations on the columns that contain them, but that just doesn't wash. Numbers are preferred over string data for sorting and comparison as well as mathematical computations. The exception to this rule is if the string of numbers you want to use starts with a zero. Take the Social Security number, for example. Other than the unfortunate fact that some Social Security numbers begin with a zero, the Social Security number would be a perfect candidate for using an integer instead of a character string. However, if you tried to store the integer 012345678, you would end up with 12345678. These two values may be numeric equivalents, but the government doesn't see it that way. They are strings of numerical characters and therefore must be stored as characters rather than as numbers.

When designing tables and choosing a data type for each column, try to be conservative and use the smallest, most efficient type possible. But at the same time, carefully consider the exception, however rare, and make sure that the chosen type will always meet these requirements.

The data types available for columns in SQL Server 2005 and 2008 are specified in the following table. Those that are unique to SQL Server 2008 are prefixed with an asterisk (*).

Data Type	Storage	Description
Integers		Note: Signed integers can be both positive and negative, whereas unsigned integers have no inherent signed value
`bigint`	8 bytes	An 8-byte signed integer. Valid values are –9223372036854775808 through +9223372036854775807.
`int`	4 bytes	A 4-byte signed integer. Valid values are –2,147,483,648 through +2,147,483,647.
`smallint`	2 bytes	A double-byte signed integer. Valid values are –32,768 through +32,767.
`tinyint`	1 byte	A single-byte unsigned integer. Valid values are from 0 through 255.
`bit`	1 bit	Integer data with either a 1 or 0 value.
Exact Numerics		
`decimal`	5–17 bytes	A predefined, fixed, signed decimal number ranging from –10000000000000000000000000000000000001 ($-10^{38}+1$) to 99999999999999999999999999999999999999 ($+10^{38}-1$). A `decimal` is declared with a precision and scale value that determines how many decimal places to the left and right are supported. This is expressed as `decimal[(precision, [scale])]`. The `precision` setting determines how many total digits to the left and right of the decimal point are supported. The `scale` setting determines how many digits to the right of the decimal point are supported. For example, to support the number 3.141592653589793, the `decimal` data type would have to be specified as `decimal(16,15)`. If the data type were specified as `decimal(3,2)`, only 3.14 would be stored. The scale defaults to zero and must be between 0 and the precision. The precision defaults to 18 and can be a maximum of 38.
`numeric`	5–17 bytes	The `numeric` data type is identical to the `decimal` data type, so use `decimal` instead, for consistency. The `numeric` data type is much less descriptive because most people think of integers as being numeric.
`money`	8 bytes	The `money` data type can be used to store values from –922,337,203,685,477.5808 to +922,337,203,685,477.5807 of a monetary unit, such as a dollar, euro, pound, and so on. The advantage of the `money` data type over a `decimal` data type is that developers can take advantage of automatic currency formatting for specific locales. Notice that the `money` data type supports figures to the fourth decimal place. Accountants like that. A few million of those ten thousandths of a penny add up after a while!

(continued)

Data Type	Storage	Description
`smallmoney`	4 bytes	Bill Gates needs the `money` data type to track his portfolio, but most of us can get by with the `smallmoney` data type. It consumes 4 bytes of storage and can be used to store values of –214,748.3648 to +214,748.3647 of a monetary unit.
Approximate Numerics		
`float`	4 or 8 bytes	The `float` data type is an approximate value (SQL Server performs rounding) that supports real numbers in the range of –1.79E + 308 to –2.23E – 308, 0 and 2.23E – 308 to 1.79E + 308. `float` can be used as a 4-byte or 8-byte data type, depending on an optional mantissa value (the number of bits used to store the mantissa of the float). `float(24)` or any value between 1 and 24 will cause the float to be defined as a 4-byte value that can store real numbers in the range of –3.40E + 38 to –1.18E – 38, 0 and 1.18E – 38 to 3.40E + 38. Any number between 25 and 53 will cause the float to be defined as an 8-bit float (aka, a double precision) in the default manner of `float(53)`.
`real`	4 bytes	The `real` data type is a synonym for a 4-byte `float`.
Date and Time Data Types		
`datetime`	8 bytes	The `datetime` data type is used to store date and time from January 1, 1753 through December 31, 9999. The accuracy of the `datetime` data type is 3.33 milliseconds.
*`datetime2`	8 bytes	The `datetime2` data type is used to store date and time from January 1, 0001 through December 31, 9999. The accuracy of the `datetime2` data type is variable but defaults to 100 nanoseconds.
`smalldatetime`	4 bytes	The `smalldatetime` data type stores date and time from January 1, 1900 through June 6, 2079, with an accuracy of 1 minute.
*`date`	3 bytes	The `date` data type stores dates only from January 1, 0001 through December 31, 9999, with an accuracy of 1 day.
*`time`	5 bytes	The `time` data type stores time-only data, with a variable precision of up to 100 nanoseconds

Data Type	Storage	Description
*datetimeoffset	10 bytes	The datetimeoffset data type is used to store date and time from January 1, 0001 through December 31, 9999. The accuracy of the datetimeoffset data type varies based on the type of server hardware SQL Server is installed on, but defaults to 100 nanoseconds if supported. When defined, the datetimeoffset data type expects a date and time string to be specified along with a time zone offset. Possible time zone offsets are between –14.00 and +14.00 hours. For example, to define a variable that is time-zone aware for Pacific Standard Time, the following code would be used: `DECLARE @PacificTime AS datetimeoffset(8)`
Character Data Types		
char	1 byte per character. Maximum 8000 characters.	The char data type is a fixed-length data type used to store character data. The number of possible characters is between 1 and 8000. The possible combinations of characters in a char data type are 256. The characters that are represented depend on what language, or collation, is defined. English, for example, is actually defined with a Latin collation. The Latin collation provides support for all English and western European characters.
varchar	1 byte per character. Up to 2GB characters.	The varchar data type is identical to the char data type, but with a variable length. If a column is defined as char(8), it will consume 8 bytes of storage even if only three characters are placed in it. A varchar column consumes only the space it needs. Typically, char data types are more efficient when it comes to processing and varchar data types are more efficient for storage. The rule of thumb is to use char if the data will always be close to the defined length, but use varchar if it will vary widely. For example, a city name would be stored with varchar(167) if you wanted to allow for the longest city name in the world, which is Krung thep mahanakhon bovorn ratanakosin mahintharayutthaya mahadilok pop noparatratchathani burirom udomratchanivetmahasathan amornpiman avatarnsathit sakkathattiyavisnukarmprasit (the poetic name of Bangkok, Thailand). Use char for data that is always the same. For example, you could use char(12) to store a domestic phone number in the United States: (123)456-7890. The 8000-byte limitation can be exceeded by specifying the (MAX) option (varchar(MAX)), which allows for the storage of 2,147,483,647 characters at the cost of up to 2GB storage space.

(continued)

Data Type	Storage	Description
`text`	1 byte per character. Maximum 2,147,483,648 characters (2GB).	The `text` data type is similar to the `varchar` data type in that it is a variable-length character data type. The significant difference is the maximum length of about 2 billion characters (including spaces) and where the data is physically stored. With a `varchar` data type on a table column, the data is stored physically in the row with the rest of the data. With a `text` data type, the data is stored separately from the actual row and a pointer is stored in the row so that SQL Server can find the text. The `text` data type is functionally equivalent to the `varchar(MAX)` data type.
`nchar`	2 bytes per character. Maximum 4000 characters (8000 bytes).	The `nchar` data type is a fixed-length type identical to the `char` data type, with the exception of the number of characters supported. `char` data is represented by a single byte and thus only 256 different characters can be supported. `nchar` is a double-byte data type and can support 65,536 different characters. The cost of the extra character support is the double-byte length, so the maximum `nchar` length is 4000 characters or 8000 bytes.
`nvarchar`	2 bytes per character. Up to 2GB.	The `nvarchar` data type is a variable-length type identical to the `varchar` data type, with the exception of the amount of characters supported. `varchar` data is represented by a single byte and only 256 different characters can be supported. `nvarchar` is a double-byte data type and can support 65,536 different characters. The cost of the extra character support is the double-byte length, so the maximum `nvarchar` length is 4000 characters or 8000 bytes. This limit can be exceeded by using the `(MAX)` option, which allows for the storage of 1,073,741,823 characters in 2GB.
`ntext`	2 bytes per character. Maximum 1,073,741,823 characters.	The `ntext` data type is identical to the `text` data type, with the exception of the number of characters supported. `text` data is represented by a single byte and only 256 different characters can be supported. `ntext` is a double-byte data type and can support 65,536 different characters. The cost of the extra character support is the double-byte length, so the maximum `ntext` length is 1,073,741,823 characters or 2GB. The `ntext` data type is functionally equivalent to the `nvarchar(MAX)` data type.
Binary Data Types		
`binary`	1–8000 bytes	Fixed-length binary data. Length is fixed when created between 1 and 8000 bytes. For example, `binary(5000)` specifies the reserving of 5000 bytes of storage to accommodate up to 5000 bytes of binary data.

Data Type	Storage	Description
varbinary	Up to 2,147,483,647 bytes	Variable-length binary data type identical to the binary data type, with the exception of consuming only the amount of storage that is necessary to hold the data. Using the (MAX) option allows for the storage of up to 2GB of binary data. However, only 1 through 8000 or MAX can be specified as storage options.
image	Up to 2,147,483,647 bytes	The image data type is similar to the varbinary data type in that it is a variable-length binary data type. The significant difference is the maximum length of about 2GB and where the data is physically stored. With a varbinary data type on a table column, the data is stored physically in the row with the rest of the data. With an image data type, however, the data is stored separately from the actual row and a pointer is stored in the row so that SQL Server can find the data. Typically, image data types are used to store actual images, binary documents, or binary objects. The image data type is functionally identical to varbinary(MAX).
Other Data Types		
timestamp	8 bytes	The timestamp data type has nothing to do with time. It is more accurately described as a data type that maintains row version data. In light of this fact, a system alias of rowversion is available for this data type and is generally preferred to avoid confusion. What timestamp actually provides is a database unique identifier to identify a version of a row. Every time a row that contains a timestamp data type is modified, the value of the timestamp changes.
uniqueidentifier	32 bytes	A data type used to store a globally unique identifier (GUID).
*hierarchyid	Up to 892 bytes	The hierarchyid data type is a variable length data type that is used to represent position in a hierarchy.
sql_variant	Up to 8016 bytes	sql_variant is used when the exact data type is unknown. It can be used to hold any data type with the exception of text, ntext, image, and timestamp.
xml	Up to 2GB	The xml data type is used to store well-formed XML. The XML stored can be specified to be well-formed fragments or complete documents and can be enforced with an XML schema bound to the variable, parameter, or column containing the XML data.

SQL Server supports additional data types, listed in the following table, that can be used in queries and programming objects, but they are not used to define columns.

Data Type	Description
cursor	The `cursor` data type is used to point to an instance of a cursor.
table	The `table` data type is used to store an in-memory rowset for processing. It was developed primarily for use with the table-valued functions that were introduced in SQL Server 2000.

Nullability

All rows from the same table have the same set of columns. However, not all columns will necessarily have values in them. For example, a new employee is hired, but he has not been assigned an extension yet. In this case, the extension column may not have any data in it. Instead, it may contain null, which means the value for that column was not initialized. Note that a null value for a string column is different from an empty string. An empty string is defined; a null is not. You should always consider a null as an unknown value. When you design your tables, you need to decide whether to allow a null condition to exist in your columns. Nulls can be allowed or disallowed on a column-by-column basis, so your employee table design could look like that shown in Figure 1-6.

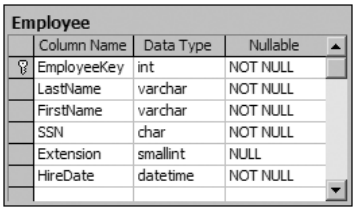

Figure 1-6

Relationships

Relational databases are all about relations. To manage these relations, you use common keys. For example, your employees sell products to customers. This process involves multiple entities:

- The employee
- The product
- The customer
- The sale

To identify which employee sold which product to which customer, you need some way to link together all the entities. Typically, these links are managed through the use of keys — primary keys in the parent table and foreign keys in the child table.

As a practical example, you can revisit the employee example. When your employee sells a product, his or her identifying information is added to the Sale table to record who the responsible employee was, as illustrated in Figure 1-7. In this case, the Employee table is the parent table and the Sale table is the child table.

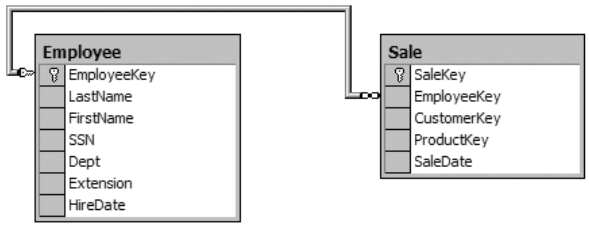

Figure 1-7

Because the same employee could sell products to many customers, the relationship between the Employee table and the Sale table is called a ***one-to-many relationship***. The fact that the employee is the unique participant in the relationship makes it the ***parent table***. Relationships are very often ***parent-child relationships***, which means that the record in the parent table must exist before the child record can be added. In the example, because every employee is not required to make a sale, the relationship is more accurately described as a ***one-to-zero-or-more relationship***. In Figure 1-7 this relationship is represented by a key and infinity symbol, which doesn't adequately model the true relationship because you don't know if the EmployeeKey field is nullable. In Figure 1-8, the more traditional and informative "crows feet" symbol is used. The relationship symbol in this figure represents an exactly one (the double vertical lines) to zero (the ring) or more (the crows feet) relationship. Figure 1-9 shows the two tables with an exactly one to one or more relationship symbol. The PK abbreviation stands for primary key, while the FK stands for foreign key. Because a table can have multiple foreign keys, they are numbered sequentially starting at 1.

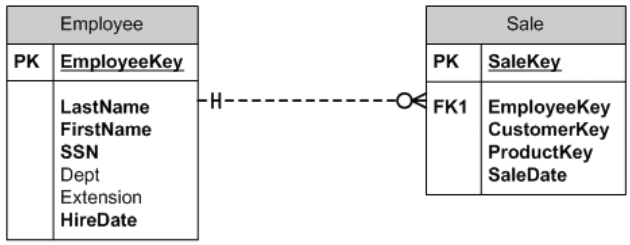

Figure 1-8

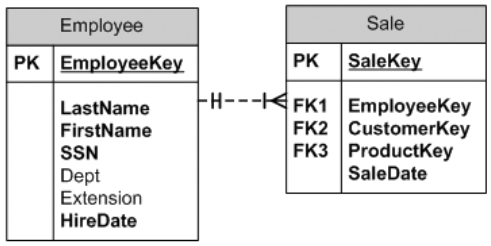

Figure 1-9

Relationships can be defined as follows:

- One-to-zero or more
- One-to-one or more
- One-to-exactly-one
- Many-to-many

The many-to-many relationship requires three tables because a many-to-many constraint would be unenforceable. An example of a many-to-many relationship is illustrated in Figure 1-10. The necessity for this relationship is created by the relationships between your entities: In a single sale many products can be sold, but one product can be in many sales. This creates the many-to-many relationship between the Sale table and the Product table. To uniquely identify every product and sale combination, you need to create what is called a ***linking table***. A linking table is simply another table that contains the combination of primary keys from the two tables, as illustrated in Figure 1-10. The Order table manages your many-to-many relationship by uniquely tracking every combination of sale and product.

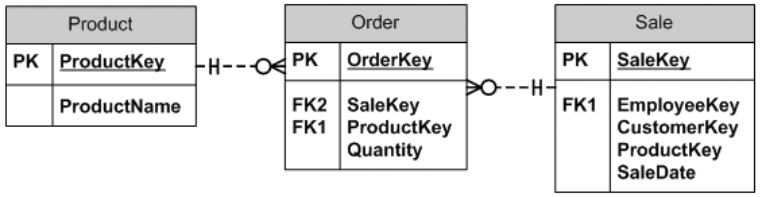

Figure 1-10

As an example of a one-to-one relationship, suppose that you want to record more detailed data about a sale, but you do not want to alter the current table. In this case, you could build a table called SaleDetail to store the data. To ensure that the sale can be linked to the detailed data, you create a relationship between the two tables. Because each sale should appear in both the Sale table and the SaleDetail table, you would create a one-to-one relationship instead of a one-to-many, as illustrated in Figures 1-11 and 1-12.

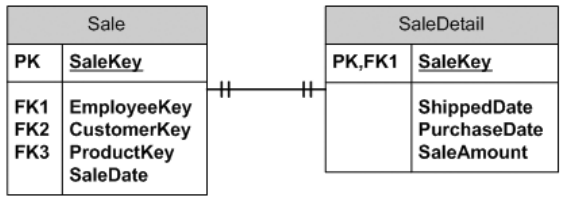

Figure 1-11

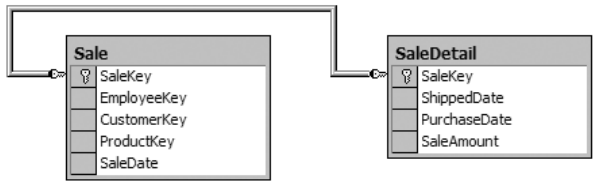

Figure 1-12

RDBMS and Data Integrity

An RDBMS is designed to maintain data integrity in a transactional environment. This is accomplished through several mechanisms implemented through database objects. The most prominent of these objects are as follows:

- Locks
- Constraints
- Keys
- Indexes

Before I describe these objects in more detail, it's important to understand two other important pieces of the SQL architecture: connections and transactions.

Connections

A connection is created anytime a process attaches to SQL Server. The connection is established with defined security and connection properties. These security and connection properties determine which data you have access to and to a certain degree, how SQL Server will behave during the duration of the query in the context of the query. For example, a connection can specify which database to connect to on the server and how to manage memory-resident objects.

Transactions

Transactions are explored in detail in Chapter 10, so for the purposes of this introduction I will keep the explanation brief. In a nutshell, a SQL Server transaction is a collection of dependent data modifications that is controlled so that it completes entirely or not at all. For example, you go to the bank and transfer $100.00 from your savings account to your checking account. This transaction involves two modifications — one to the checking account and the other to the savings account. Each update is dependent on the other. It is very important to you and the bank that the funds are transferred correctly, so the modifications are placed together in a transaction. If the update to the checking account fails but the update to the savings account succeeds, you most definitely want the entire transaction to fail. The bank feels the same way if the opposite occurs.

With a basic idea about these two objects, let's proceed to the four mechanisms that ensure integrity and consistency in your data.

Locks

SQL Server uses locks to ensure that multiple users can access data at the same time with the assurance that the data will not be altered while they are reading it. At the same time, the locks are used to ensure that modifications to data can be accomplished without affecting other modifications or reads in progress. SQL Server manages locks on a connection basis, which simply means that locks cannot be held mutually by multiple connections. SQL Server also manages locks on a transaction basis. In the same way that multiple connections cannot share the same lock, neither can transactions. For example, if an application opens a connection to SQL Server and is granted a shared lock on a table, that same application cannot open an additional connection and modify that data. The same is true for transactions. If an application begins a transaction that modifies specific data, that data cannot be modified in any other transaction until the first has completed its work. This is true even if the multiple transactions share the same connection.

SQL Server utilizes six lock types, or more accurately, six resource lock modes:

- Shared
- Update
- Exclusive
- Intent
- Schema
- Bulk Update

Shared, update, exclusive, and intent locks can be applied to rows of tables or indexes, pages (8-kilobyte storage page of an index or table), extents (64-kilobyte collection of eight contiguous index or table pages), tables, or databases. Schema and bulk update locks apply to tables.

Shared Locks

Shared locks allow multiple connections and transactions to read the resources they are assigned to. No other connection or transaction is allowed to modify the data as long as the shared lock is granted. Once an application successfully reads the data, the shared locks are typically released, but this behavior can be modified for special circumstances. For instance, a shared lock might be held for an entire transaction to ensure maximum protection of data consistency by guaranteeing that the data that a transaction is based on will not change until the transaction is completed. This extended locking is useful for situations where transactional consistency must be 100% assured, but the cost of holding the locks is that concurrent access to data is reduced. For example, you want to withdraw $100.00 from your savings account. A shared lock is issued on the table that contains your savings account balance. That data is used to confirm that there are enough funds to support the withdrawal. It would be advantageous to prevent any other connection from altering the balance until after the withdrawal is complete. Shared locks are compatible with other shared locks so that many transactions and connections can read the same data without conflict.

Update Locks

Update locks are used by SQL Server to help prevent an event known as a ***deadlock***. Deadlocks are bad. They are mostly caused by poor programming techniques. A deadlock occurs when two processes get into a standoff over shared resources. Let's return to the banking example: In this hypothetical banking transaction both my wife and I go online to transfer funds from our savings account to our checking account. We somehow manage to execute the transfer operation simultaneously and two separate processes are launched to execute the transfer. When my process accesses the two accounts, it is issued shared locks on the resources. When my wife's process accesses the accounts, it is also granted a shared lock to the resources. So far, so good, but when our processes try to modify the resources, pandemonium ensues. First my wife's process attempts to escalate its lock to exclusive to make the modifications. At about the same time my process attempts the same escalation. However, our mutual shared locks prevent either of our processes from escalating to an exclusive lock. Because neither process is willing to release its shared lock, a deadlock occurs.

SQL Server doesn't particularly care for deadlocks. If one occurs, SQL Server will automatically select one of the processes as a victim and kill it. SQL Server selects the process with the least cost associated with it, kills it, rolls back the associated transaction, and notifies the responsible application of the termination by returning error number 1205. If properly captured, this error informs the user that

"Transaction ## was deadlocked on *x* resources with another process and has been chosen as the deadlock victim. Rerun the transaction." To avoid the deadlock from ever occurring, SQL Server will typically use update locks in place of shared locks. Only one process can obtain an update lock, preventing the opposing process from escalating its lock. The bottom line is that if a read is executed for the sole purpose of an update, SQL Server may issue an update lock instead of a shared lock to avoid a potential deadlock. This can all be avoided through careful planning and implementation of SQL logic that prevents the deadlock from ever occurring.

Exclusive Locks

SQL Server typically issues exclusive locks when a modification is executed. To change the value of a field in a row, SQL Server grants exclusive access of that row to the calling process. This exclusive access prevents a process from any concurrent transaction or connection from reading, updating, or deleting the data being modified. Exclusive locks are not compatible with any other lock types.

Intent Locks

SQL Server issues intent locks to prevent a process from any concurrent transaction or connection from placing a more exclusive lock on a resource that contains a locked resource from a separate process. For example, if you execute a transaction that updates a single row in a table, SQL Server grants the transaction an exclusive lock on the row, but also grants an intent lock on the table containing the row. This prevents another process from placing an exclusive lock on the table.

Here is an analogy I often use to explain the intent lock behavior in SQL programming classes: You check in to Room 404 at the SQL Hotel. You now have exclusive use of the fourth room on the fourth floor (404). No other hotel patron will be allowed access to this room. In addition, no other patron will be allowed to buy out every room in the hotel because you have already been given exclusive control to one of the rooms. You have what amounts to an intent exclusive lock on the hotel and an exclusive lock on Room 404. Intent locks are compatible with any less-exclusive lock, as illustrated in the following table on lock compatibility.

	Existing Granted Lock				
Requested Lock Type	**IS**	**S**	**U**	**IX**	**X**
Intent shared (IS)	Yes	Yes	Yes	Yes	No
Shared (S)	Yes	Yes	Yes	No	No
Update(U)	Yes	Yes	No	No	No
Intent exclusive (IX)	Yes	No	No	Yes	No
Exclusive (X)	No	No	No	No	No

Schema Locks

There are two types of schema locks SQL Server will issue on a table: schema modification locks (Sch-M) and schema stability locks (Sch-S). Schema modification locks prevent concurrent access to a table while the table is undergoing modification — for example, a name change or a column addition. A schema stability lock prevents the table from being modified while it is being accessed for data retrieval.

Bulk Update Locks

A bulk update lock on a table allows multiple bulk load threads to load data into a table while preventing other types of data access. Bulk update locks are issued when table locking is enabled at the table or the chosen as an option with the bulk operation.

Key Range Locks

Key-range locks protect a range of rows implicitly included in a record set being read by a Transact-SQL statement while using the serializable transaction isolation level. The serializable isolation level requires that any query executed during a transaction must obtain the same set of rows every time it is executed during the transaction. A key range lock protects this requirement by preventing other transactions from inserting new rows whose keys would fall in the range of keys read by the serializable transaction.

SQL Server and Other Products

Microsoft has plenty of competition in the client/server database world and SQL Server is a relatively young product by comparison. However, it has enjoyed wide acceptance in the industry due to its ease of use and attractive pricing. If our friends at Microsoft know how to do anything exceptionally well, it's taking a product to market so it becomes very mainstream and widely accepted.

Microsoft SQL Server

Here is a short history lesson on Microsoft's SQL Server. Originally, SQL Server was a Sybase product created for IBM's OS/2 platform. Microsoft engineers worked with Sybase and IBM but eventually withdrew from the project. Then, Microsoft licensed the Sybase SQL Server code and ported the product to work with Windows NT. It took a couple of years before SQL Server really became a viable product. The SQL Server team went to work to create a brand new database engine using the Sybase code as a model. They eventually rewrote the product from scratch.

When SQL Server 7.0 was released in late 1998, it was a major departure from the previous version, SQL Server 6.5. SQL Server 7.0 contained very little Sybase code with the exception of the core database engine technology, which was still under license from Sybase. SQL Server 2000 was released in 2000 with many useful new features, but was essentially just an incremental upgrade of the 7.0 product. SQL Server 2005, however, is a major upgrade and some say it's the very first completely Microsoft product. Any vestiges of Sybase are long gone. The storage and retrieval engine has been completely rewritten, the .NET Framework has been incorporated, and the product has significantly risen in both power and scalability. SQL Server 2008 is to SQL Server 2005 what SQL Server 2000 was to SQL Server 7.0. There are some very interesting and powerful improvements to the server, which we will address in the coming chapters, but the changes are not as dramatic as the changes that SQL Server 2005 brought.

Oracle

Oracle is probably the most recognizable enterprise-class database product in the industry. After IBM's E. F. Codd published his original papers on the fundamental principles of relational data storage and design in 1970, Larry Ellison, founder of Oracle, went to work to build a product to apply those principles. Founded in 1977, Oracle has had a dominant place in the database market for quite some time with a comprehensive suite of database tools and related solutions. Versions of Oracle run on UNIX, Linux, and Windows server operating systems.

The query language of Oracle is known as Procedure Language/Structured Query Language (PL/SQL). Indeed, many aspects of PL/SQL resemble a C-like procedural programming language. This is evidenced by syntax such as command-line termination using semicolons. Unlike T-SQL, statements are not actually executed until an explicit run command is issued (preceded with a single line containing a period.) PL/SQL is particular about using data types and includes expressions for assigning values to compatible column types.

IBM DB2

This is really where it all began. Relational databases and the SQL language were first conceptualized and then implemented in IBM's research department. Although IBM's database products have been around for a very long time, Oracle (then Relational Software) actually beat them to market. DB2 database professionals perceive the form of SQL used in this product to be purely ANSI SQL and other dialects such as Microsoft's T-SQL and Oracle's PL-SQL to be more proprietary. Although DB2 has a long history of running on System 390 mainframes and the AS/400, it is not just a legacy product. IBM has effectively continued to breathe life into DB2 and it remains a viable database for modern business solutions. DB2 runs on a variety of operating systems today, including Windows, UNIX, and Linux.

Informix

This product had been a relatively strong force in the client/server database community, but its popularity waned in the late 1990s. Originally designed for the UNIX platform, Informix is a serious enterprise database. Popularity slipped over the past few years, as many applications built on Informix had to be upgraded to contend with year 2000 compatibility issues. Some organizations moving to other platforms (such as Linux and Windows) have also switched products. The 2001 acquisition of Informix nudged IBM to the top spot over Oracle as they brought existing Informix customers with them. Today, Informix runs on Linux and integrates with other IBM products.

Sybase SQLAnywhere

Sybase has deep roots in the client/server database industry and has a strong product offering. At the enterprise level, Sybase products are deployed on UNIX and Linux platforms and have strong support in Java programming circles. At the mid-scale level, SQLAnywhere runs on several platforms, including UNIX, Linux, Mac OS, NetWare, and Windows. Sybase has carved a niche for itself in the industry for mobile device applications and related databases.

Microsoft Access (Jet)

To be perfectly precise, Access is not really a database platform. Access is a Microsoft Office application that is built to use the Microsoft Jet database platform. Access and Jet were partially created from the ground up but also leverage some of the technology gleaned from Microsoft's acquisition of FoxPro. As a part of Microsoft's Office Suite, Access is a very convenient tool for creating simple business applications. Although Access SQL is ANSI 92 SQL–compliant, it is quite a bit different from T-SQL. For this reason, I have made it a point to identify some of the differences between Access and T-SQL throughout the book.

Access has become the non-programmer's application development tool. Many people get started in database design using Access and then move on to SQL Server as their needs become more sophisticated. Access is a powerful tool for the right kinds of applications, and some commercial products have actually been developed using Access. Unfortunately, because Access is designed (and documented) to be an end user's tool rather than a software developer's tool, many Access databases are often poorly designed and power users learn through painful trial and error about how not to create database applications.

The Jet Database Engine was designed in 1992. Jet is a simple and efficient storage system for small to moderate volumes of data and for relatively few concurrent users, but it falls short of the stability and fault-tolerance of SQL Server. For this reason, a desktop version of the SQL Server engine (now called SQL Server Express, but formally known as Microsoft SQL Desktop Engine [MSDE]) has shipped with Access since Office 2000. SQL Server Express is an alternative to using Jet and really should be used in place of Jet for any serious database. Starting smaller-scale projects with SQL Server Express provides an easier path for migrating them to full-blown SQL Server editions later on.

MySQL

MySQL is a developer's tool embraced by the open source community. Like Linux and Java, it can be obtained free of charge and includes source code. Compilers and components of the database engine can be modified and compiled to run on most any computer platform. Although MySQL supports ANSI SQL, it promotes the use of an application programming interface (API) that wraps SQL statements. As a database product, MySQL is a widely accepted and capable product. However, it appeals more to the open source developer than to the business user.

Many other database products on the market may share some characteristics of the products discussed here. The preceding list represents the most popular database products that use ANSI SQL.

Summary

Microsoft SQL Server 2005 has earned a very good reputation in the marketplace and remains a very capable and powerful database management server. SQL Server 2005 took T-SQL and database management a huge step forward. Now SQL Server 2008 promises to continue the maturation of the product with new and very powerful T-SQL commands and functions.

The upcoming chapters explore most of the longstanding features and capabilities of T-SQL and preview the awesome new capabilities that SQL Server 2005 and SQL Server 2008 have brought to the field of T-SQL programming. So sit back and hold on; it's going to be an exciting ride.

If the whole idea of writing T-SQL code and working with databases doesn't thrill you like it does me, I apologize for my overt enthusiasm. My wife has reminded me on many occasions that no matter how I may look, I really am a geek. I freely confess it. I also eagerly confess that I love working with databases. Working with databases puts you in the middle of everything in information technology. There is absolutely no better place to be. Can you name an enterprise application that doesn't somehow interface with a database? You see? Databases are the sun of the IT solar system!

In the coming months and years you will most likely find more and more applications storing their data in a SQL Server database, especially if that application is carrying a Microsoft logo. Microsoft Exchange Server doesn't presently store its data in SQL, but it will. Active Directory will also reportedly move its data store to SQL Server. Microsoft has been exploring for years the possibility and feasibility of moving the Windows file system itself to a SQL-type store. For the T-SQL programmer and Microsoft SQL Server professional, the future is indeed bright.